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WASHINGTON, D. C.
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SKELETAL MATURING IN ADOLESCENCE AS A BASIS FOR DETERMINING PERCENTAGE OF COMPLETED GROWTH

by

NANCY BAYLEY

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SKELETAL MATURING IN ADOLESCENCE AS A BASIS FOR DETERMINING PERCENTAGE OF COMPLETED GROWTH

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INTRODUCTION

Recent studies of skeletal development have furnished us with standards which allow for significant differentiation of skeletal maturity, within homogeneous chronological age groups, throughout the span of childhood. These standards, in the form of x-ray pictures, give us a valuable instrument for measuring an important aspect of anatomical development. In the Adolescent Growth Study of the Institute of Child Welfare, x-rays of the left hand and knee were taken at six-month intervals on 90 boys and 87 girls, beginning when the subjects averaged 14 years of age, and continuing for 4 1/2 years. Thus, most of the cases were x-rayed nine times unless complete epiphyseal closure rendered further records unnecessary.

SAMPLE

The selection of cases for this study has been described elsewhere (6). At the time the study started, they were members of the fifth grade in several Oakland public schools which are located in districts representing a range in socio-economic status similar to that of Oakland as a whole. The majority of the cases (87 per cent) are of "Old American" or North European stock, but there are a few (11 boys and 12 girls) who do not fit into this classification. These 23 children who are racially different from the principal group include 13 Italians (4 boys and 9 girls), 4 Jews (1 boy and 3 girls), 2 boys who are part Spanish, and 4 boys who are respectively Hungarian, Armenian, Mexican and part Tahitian.

THE SKELETAL DATA: METHODS, ADEQUACY AND SELECTION OF CRITERIA

The x-rays have been assessed according to the Todd standards (11, 12) which furnish norms for the sexes separately throughout childhood, standards being spaced at six-month intervals from the age of 3 years until complete closure of the epiphyses.[1]

Assessments made from these standards have been found to be adequately reliable (Table 1) (2, 8). In this sample correlation coefficients have been computed between two independent assessments by the same rater for each six-month age interval,[2] for nine successive ages. These r's, for the boys' x-rays, range from .93 to .97 for the hands and from .87 to .96 for the knees. Two separate raters agreed with each other almost as well for two sets of films (age range 2 years, S.D. 6 months) the r's being .92 and .94 for hands, and .91 and .85 for knees. Reliabilities are similarly high for the girls, but could be computed for only a few age levels in this study because of the early age at which girls reach maturity. For five ages the girls' r's for the hand assessments (first by second rating) range from .93 to .98, and for the knees from .91 to .96. The final assessments used in all comparisons of skeletal maturity are based on at least two independent ratings.

TABLE 1

CORRELATIONS BETWEEN FIRST AND SECOND INDEPENDENT ASSESSMENTS OF SKELETAL MATURITY

C.A.	Hands				Knees			
	Boys		Girls		Boys		Girls	
	n	r	n	r	n	r	n	r
13.7	40	.89	39	.93	41	.95	39	.91
14.2	72	.95	67	.94	72	.89	68	.96
14.7	78	.94	82	.96	78	.93	82	.95
15.2	81	.97	77	.98	80	.96	77*	.96*
15.7	76	.96	63	.97	76	.90	63*	.92*
16.2	74	.93			75	.91		
16.7	74	.93			74	.87		
17.2	74	.96			74*	.90*		
17.7	60	.96			60*	.91*		
18.2	31	.95*						

*Skewed distribution

[1] *The relative merits of available standards have been discussed in an earlier paper (2). The decision was reached that, for use with our data, the Todd standards are the best now available.*

[2] *The age-intervals used in this study have been selected to coincide with those used in the Todd standards, that is, 14.0 to 14.4, with the mid-point at 14.2 years.*

Where the first and second rating did not agree a third rating was made, and if necessary, additional ones, until agreement occurred two or more times. Hence, the reliabilities of the final assessments used are higher than those given here for single ratings.

The ratings described above were made by what we may call the cross-sectional method; i.e., all of the x-rays taken at a single grade-level were assessed independently of any child's earlier or later x-rays. It appeared that a further check on this method of rating could be made, and possibly better results could be achieved by re-assessing each child's films, seriatim - that is, by spreading out in a row all of his films for the same bone area, and comparing them with the standards in series. Assessments made by the cross-sectional method had resulted in several instances in which a child appeared at a later age to have regressed to a less mature status than that assigned at an earlier age. The 5 boys with such reversals, with the addition of a random selection of 27 others, (enough to make an adequate number for statistical comparisons) were re-assessed, seriatim. This, of course, does not form a representative sample, but instead is heavily weighted with the least reliably assessed cases. The seriatim ratings eliminated all apparent regressions in maturity (it was clear from re-inspection of the films that no child had actually regressed), and in addition made the rate of progress of a number of cases more regular than had appeared from the original cross-sectional ratings. Examples are given in Table 2. Obviously, for a number of children, a truer picture of their growth rates is obtained by the seriatim assessments. However, such a re-rating of all cases would be laborious, and it cannot be recommended for general use since the procedure is one that can be used only in the terminal stages of a longitudinal study. For the 32 boys who had been re-assessed by this method an investigation was made of the extent of the advantage to be derived from this more careful procedure. On a total of 261 x-rays, for these 32 boys, the cross-section assessments were found to correlate .987 with the seriatim assessments. For those assessments made at the ages 15.0 to 15.4 inclusive (a single x-ray for each boy), the r was .957. (This particular age was chosen because it was the only age at which all 32 boys were represented.) The average absolute difference of the 261 ratings is .15 of a year. In general the differences between the two methods of rating have been magnified by the selection of cases, and even though the seriatim assessments have corrected errors in a number of instances, it was decided, because of the time it would take, not to re-assess the additional cases in which we should expect fewer and smaller errors.

TABLE 2

COMPARISON OF RATINGS MADE BY CROSS-SECTIONAL AND SERIATIM ASSESSMENTS OF THE HANDS OF FOUR BOYS

Serial Order of X-ray (6-month intervals)	Case F 11		Case E 8		Case A 11		Case E 23	
	I*	II*	I	II	I	II	I	II
1	26**	26	23	22	19	19	21	21
2	28	27+	23	23+	19+	20+	21	22
3	29	28	25	25	21	21	22	23
4	28+	28+	26	26	22	22	24	24
5	29	29	26	27	24	24	24	25-
6	31	31	28	28-	24	24	25+	25+
7	31	31+	29	28	26	26-	27+	27+
8	-	-	28	29	26	26	29	29
9	32	32	31	31	-	-	30	30

*The assessments in columns labeled I were made independently of other records for the same child; those in columns marked II were made with all of a child's x-rays laid out in series for comparisons.

**These numbers are the ones Todd originally assigned to his hand standards, which were numbered consecutively starting with number 1 for the 3-year standard. Each number represents a six-month step in the series.

For the most part, this group of children appears to be similar to those from whom Todd derived his standards. Means and S. D.'s are given in Table 3. The only marked deviation occurs in the boys' knees at the ages 17.0 to 17.4. Here the mean skeletal age assessment for our group is only 16.9, indicating relative immaturity in the Oakland boys as compared with Todd's Cleveland standardization sample. However, the actual rates of change at this stage of maturity are very slow - much slower than at earlier ages - and for this reason the retardation may not be significant. Such retardation as does occur might be due to any of several factors, such as a slowing down of growth rates, or some consistent error in the knee standards, or in the interpretation of the standards at this level.[3]

In the present treatment of the data the assessments of the hand and knee are averaged to form a single skeletal age, in order to secure a more reliable and comprehensive indicator of the developmental status of the skeleton. Let us consider the reasons for this choice. As we have seen, the ratings of the hands appear to be slightly more reliable than those of the

[3]*By this last possibility, I refer to the fact that some of of the standards are rather ambiguous and more difficult to interpret than the others. We have found a tendency to avoid assigning the ratings which these less clear standards represent.*

TABLE 3

MEANS AND STANDARD DEVIATIONS (S.D.) OF SKELETAL AGE RATINGS BY HALF-YEAR INTERVALS, GIVEN IN YEARS AND DECIMALS OF A YEAR

C.A.	Hands						Knees					
	Boys			Girls			Boys			Girls		
	n	Mean	S.D.	n	Mean	S.D.	n	Mean	S.D.	n	Mean	S.D.
13.2	15	13.1	.8	11	13.2	.9	15	13.1	.6	11	13.3	1.1
13.7	40	13.6	.9	39	13.9	1.0	40	13.7	.8	39	13.9	1.0
14.2	75	14.1	1.0	73	14.4	1.0	76	14.2	.9	72	14.4	1.1
14.7	84	14.8	1.0	87	14.9	1.0	83	14.7	1.0	87	14.9	1.0
15.2	90	15.1	1.0	81	15.3	.9	90	15.2	1.0	81	15.3	.9
15.7	81	15.7	1.0	78	15.6	.8	80	15.6	.8	78	15.6	.8
16.2	79	16.3	.9				80	16.2	.8			
16.7	75	16.7	1.0				75	16.5	.8			
17.2	73	17.3	.9				73	16.9	.7			

knees. Furthermore, the two areas correlate highly in bone maturity (Table 4): the r's between hand and knee range from .85 to .88 for the boys, and from .86 to .90 for the girls (r's computed for each half-year age interval). If one x-ray area were to be depended upon, the hand is the obvious choice, because of the greater reliability in assessment. However, as shown in Table 5 and illustrated for one series in Figure 1, the combined assessments give higher inter-year correlations over a period of years than either the hand or knee alone, indicating greater consistency and a more stable measure when assessments for both areas of the body are combined. It may also be assumed that errors in assessment tend to cancel out in the combination.

Using this measure of skeletal age, we have made comparisons with other physical aspects of development in the same group of children. One limitation set on the comparisons of our skeletal data with the other material is that the x-rays were not obtained in the initial years of the study. Hence, emphasis must be placed on the terminal, and near-terminal points of skeletal growth. This limitation, however, may not be very serious because there are definite advantages in using a terminal or relatively static point in the growth process as a basis for comparisons in the study of growth. From the standpoint of physical growth, there is much to be said for taking as a standard the point at which complete epiphyseal union is achieved (i.e., maturity on the Todd standards) and the final size of the skeleton is determined. There will be little subsequent deviation from this, and any changes which do occur are very slight in comparison with those which have gone before.

TABLE 4

CORRELATIONS BETWEEN SKELETAL AGE ASSESSMENTS OF HAND AND KNEE X-RAYS

	Boys		Girls	
C.A.	n	r	n	r
13.7	40	.88	39	.90
14.2	72	.85	68	.88
14.7	78	.85	82	.89
15.2	80	.88	77	.89
15.7	76	.86	63*	.88*
16.2	74	.85	63*	.86*
16.7	74	.87		
17.2	74	.87		
17.7	60*	.82*		

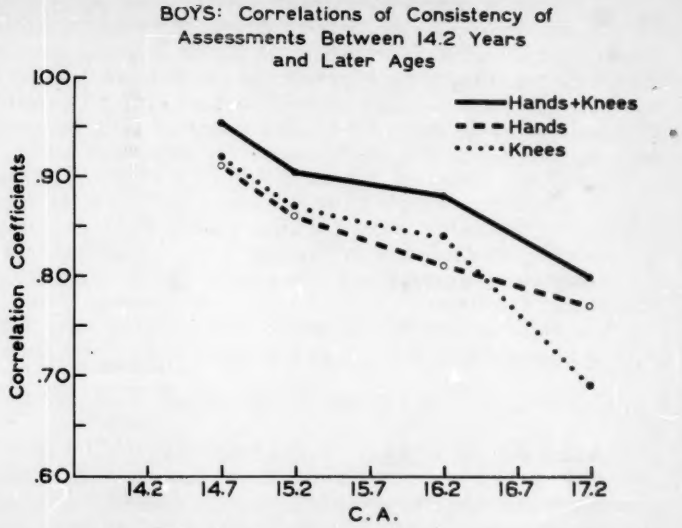
*Skewed distribution

TABLE 5

CORRELATIONS FOR CONSISTENCY IN SKELETAL ASSESSMENTS

	BOYS					
	Hands		Knees		Hand-Knee Average	
	Assessments at 13.7 Years with Later Ages					
C.A.	n	r	n	r	n	r
14.2	34	.91	34	.87	34	.96
14.7	40	.84	40	.84	37	.90
15.7	32	.70	31	.76	31	.79
	Assessments at 14.2 Years with Later Ages					
14.7	67	.92	66	.91	63	.95
15.2	69	.86	72	.87	64	.90
16.2	58	.81	59	.84	57	.88
17.2	57	.77	58	.69	57	.80
	Assessments at 14.7 Years with Later Ages					
15.2	76	.92	76	.87	71	.94
15.7	73	.90	72	.79	66	.91
16.7	70	.88	70	.80	66	.88
	Assessments at 15.2 Years with Later Ages					
15.7	79	.92	81	.85	72	.94
16.2	78	.87	68	.84	71	.90
17.2	71	.84	72	.77	70	.87
	Assessments at 15.7 Years with Later Ages					
16.2	73	.91	73	.84	69	.94
16.7	70	.92	69	.88	67	.93
	GIRLS					
	Assessments at 13.7 Years with Later Ages					
14.2	39	.92	39	.86	37	.94
14.7	40	.92	40	.84	38	.91
	Assessments at 14.2 Years with Later Ages					
14.7	73	.93	72	.91	67	.95

Figure 1



Relative deviation from such a stable position can then be expressed for other ages and data.

The exact points of maturity which we selected differ for the sexes - a difference necessitated by the nature of our data. At the time the first x-rays were taken four of the girls had already attained complete closure of the epiphyses of hand and knee. At the time of the last examination all but eleven of the girls had reached skeletal maturity. It is possible, then, to determine for most of the girls the age at which complete closure occurred (a skeletal age of 16 years, 3 months on the Todd standards). The situation for the boys is considerably different, because they mature, on the average, 2 years later than the girls. The Todd standards represent complete closure of the epiphyses of the boys' hands at 18 years, 9 months and of their knees at 18 years, 3 months. At the time our data collection was discontinued less than half of the boys had reached this mature status. However, all but seven had reached the standard of 17 years, 3 months. Since this is in fact so close to the mature status that the subsequent changes are very slight, the standard of 17 years, 3 months, for the boys, has been chosen as a basis for comparisons with other ages.

THE ANTHROPOMETRIC DATA

A series of anthropometric measures was taken at the time of the physical examination. These measures were obtained every 6 months throughout the period of data collection, starting in the fifth grade at an average age of approximately 11 years. All measures were made in the nude, using a carefully standardized procedure. Each child was measured independently by two physicians; where measurements disagreed by a centimeter or more, the measurements were repeated. Measuring instruments include an adaptation of Baldwin's (1) paper scale and triangle for height and stem length; the linen tape and wooden calipers described by Franzen (5) for girths and transverse diameters, respectively; and balance scales calibrated in kilograms for weights.

The anthropometric data will be described in more detail in forthcoming publications from the Adolescent Growth Study.

RELATIVE SIZE IN TERMS OF SKELETAL MATURITY

Having set up a standard of "maturity", in terms of a given skeletal age and the physical characteristics which accompany that age, it is possible to convert the anthropometric dimensions at other ages into percentages of "mature" size. The use of percentages expresses the relationship between skeletal and physical growth in terms of the individual's own relative maturity, and eliminates the complicating factor of individual differences in size.[4] If a boy has a given skeletal status, for example that of the average 14 year-old, then what proportion of his adult stature has he attained - how nearly is he "grown up", not only in this but in a variety of physical and physiological traits? In order to investigate this problem, measures obtained at the selected skeletal ages of 16 years, 3 months for girls and 17 years, 3 months for boys are taken as a base. For purposes of convenience, the term "mature" will be used to refer to the status of the subjects at these respective ages. The point which is selected as mature is to a certain

[4] *Since these computations were made on our material a publication has appeared from the Harvard Growth Study (4) in which the same principle was used. In the Harvard data the latest measure taken was used as 100% and earlier measures were expressed as per cent of adult size as thus determined. This was done primarily in order to obtain an accurate valuation of bone maturity on the sum of 12 diameters of bones in the hand. Although similar computations were made from other data, their significance is not discussed, and only a few individual growth curves occur in the publication.*

extent arbitrary, and although it does not represent exactly the same skeletal status in both sexes, it will be more convenient to use the same term for both, always keeping in mind the sex differences. It should also be borne in mind that for both boys and girls the points selected are so close to maturity that growth changes subsequent to these ages are very minor in nature.

Measures made at the time a boy or girl first attained his or her "mature" skeletal age, were assigned a status of 100 per cent.[5] For height, stem length, and bi-iliac diameter, the per cent of this standard measure was then computed for all measures taken on the group at all ages. The resulting percentages give us figures for each child's size, relative to status at maturity.

The average trends of relative size - i.e., per cent of mature size gained at successive ages - are shown in Table 6. A comparison of the means based on chronological age and on skeletal age shows that the two series are almost identical. When the means for the sexes are compared for the same stage of skeletal maturity[6] (i.e., an approximate two-year difference in chronological age), they also are seen to be very similar. For example, at 15.2 years the boys have attained 96.59 per cent of their mature height as compared with the girls at 13.2 years who have attained 96.56 per cent of their mature height.

The striking differences between the chronological age and the skeletal age data are to be found in their standard deviations. When percentage of mature height is classified according to chronological age there is considerable spread of the percentage values except close to the point of maturity. But when skeletal age is made the basis for groupings, the S. D.'s shrink markedly, showing that relative size is much more closely related to skeletal maturity than to chronological age.

[5] *Because of imperfect reliability of the measures, individual growth-curves for each measure of each child were inspected and where the measurement at the 100 per cent point deviated widely from a child's own growth trend the curve was smoothed (by a 3-point moving average) and an interpolated figure read from the curve was taken as the 100 per cent value. In computing percentages from this value, however, the actual obtained measures were used.*

[6] *The term "skeletal maturity", as used in this paper, refers to the degree of development of the skeleton while "skeletal age" refers to the Todd age standards, which are different for boys and girls. Hence, for the adolescent period under consideration, a boy and a girl of the same skeletal age would differ about two years in skeletal maturity.*

TABLE 6

MEANS AND STANDARD DEVIATIONS (S.D.) OF PER CENT OF MATURE SIZE ATTAINED AT SUCCESSIVE AGES

	BOYS						GIRLS					
	Chronological Age Groupings			Skeletal Age Groupings			Chronological Age Groupings			Skeletal Age Groupings		
Ages	n	Mean	S.D.	n	Mean	S.D.	n	Mean	S.D.	n	Mean	S.D.
					Height							
10.7	38	80.2	2.0				33	87.1	3.0			
11.2	49	81.7	2.2				51	89.0	3.2			
11.7	67	83.1	2.3				65	91.0	3.6			
12.2	67	84.6	2.5				65	93.0	3.2			
12.7	75	86.5	2.9	7	87.5	.8	68	95.0	2.7			
13.2	73	88.6	3.3	21	89.2	1.5	65	96.6	2.2**	16	96.9	.9
13.7	75	90.9	3.5	22	91.4	1.4	71	97.6	1.9**	18	97.8	.4
14.2	71	93.0	3.5	38	93.0	1.7	71	98.0	1.5**	27	98.5	.5
14.7	75	94.9	3.1	47	95.0	1.6	70	99.0	1.1**	37	98.8	.6
15.2	70	96.6	2.4	52	96.8	1.0	66	99.5	.7**	49	99.3	.3
15.7	71	97.9	1.7	58	98.1	.7	64	99.8	.6	53	99.5	.3
16.2	64	99.0	1.1	55	98.9	.6	68	99.9	.4	72	100.0*	.1*
16.7	70	99.5	.8	60	99.6	.3	65	100.1	.3			
17.2	64	100.0*	.6*	55	100.0*	.2*	63	100.2	.3			
17.7	56	100.2	.4	44	100.2	.3	48	100.3	.3			
18.2	29	100.4	.3	34	100.5	.3	12	100.6	.3			
					Stem Length							
10.7	38	80.3	1.8				33	85.3	3.0			
11.2	49	81.0	2.0				51	87.2	3.2			
11.7	67	82.1	2.2				65	88.8	3.6			
12.2	67	83.2	2.4				65	90.3	4.0			
12.7	75	84.8	2.7				68	92.9	3.3			
13.2	73	86.6	3.1	21	87.2	1.5	65	94.7	2.7	16	94.9	1.3
13.7	75	88.8	3.5	22	89.4	1.5	71	96.1	2.6	18	96.0	.8
14.2	71	90.9	3.7	38	91.0	2.0	71	97.2	2.2	27	97.0	1.0
14.7	75	93.2	3.5	47	93.1	1.9	69	98.2	1.8	37	97.7	.8
15.2	70	95.3	2.8	52	95.3	1.3	62	99.0	1.4	49	98.7	1.0
15.7	71	96.9	2.3	58	97.1	1.3	64	99.4	1.3	51	98.9	.8
16.2	64	98.5	1.6	55	98.1	1.0	67	99.9	1.1*	72	100.0*	.3*
16.7	70	99.3	1.2	60	99.2	.7	65	100.1	.7			
17.2	64	100.0	.9	55	100.0*	.5*	62	100.4	.8			
17.7	56	100.3	.7	44	100.3	.4	48	100.5	.6			
18.2	29	100.5	.6	34	100.6	.4	12	100.8	.7			
					Bi-iliac Diameter							
10.7	38	79.8	3.3				33	82.9	4.7			
11.2	49	81.0	2.8				51	85.1	4.4			
11.7	67	82.6	3.0				65	86.8	4.8			
12.2	67	84.5	3.0				65	88.6	4.6			
12.7	75	86.3	3.5				68	91.0	4.4			
13.2	73	88.3	3.6	21	89.2	1.6	65	92.6	4.1	16	92.7	1.8
13.7	75	90.3	3.7	22	90.4	1.6	71	94.3	3.6	18	94.4	1.2
14.2	71	92.6	3.8	38	92.2	2.4	71	95.8	3.1	27	95.1	2.0
14.7	75	94.3	3.5	47	94.6	2.0	70	97.3	3.1	37	96.2	1.7
15.2	70	96.1	2.9	52	96.2	1.9	64	98.2	2.4	49	97.7	1.7
15.7	71	97.6	2.4	58	97.9	1.3	64	99.0	2.4	52	98.6	1.2
16.2	64	99.0	1.5	55	98.7	1.0	67	100.2	1.8	72	100.1*	1.1*
16.7	70	99.4	1.3	60	99.5	.8	65	100.3	1.6			
17.2	64	100.0	1.0	55	100.2*	.5*	63	100.9	1.7			
17.7	56	100.2	1.0	44	100.2	.7	48	100.7	2.2			
18.2	29	100.3	.7	34	100.7	1.0	12	101.3	1.5			

*Distributions not normal because these are at the point chosen as mature status and 100 per cent.

**Skewed distributions because of mature status of some cases.

This relationship is illustrated in the individual curves in Figures 2 to 25, in which per cent of mature size is plotted first in terms of the child's chronological age, then according to his skeletal age. In these charts[7] the line of means is indicated in the center of a shaded area representing ± 1 P.E. from the mean. The horizontal lines from the ordinate, and the vertical lines from the abscissa, terminate at ± 2 P.E. from the mean. The heavy black circles designate the seriatim values for an individual case. The cases selected are among the most extremely deviating boys, Cases F 5 and E 10 are early-maturing, while A 1 and B 20 are late-maturing. A glance at these figures reveals that the most consistent trends are found in height - probably at least in part because it is the most reliable measure.

When chronological age is held nearly constant by grouping the boys into six-month age intervals, r's of skeletal age with absolute height at each age level are all positive, but they gradually diminish at successive ages, from .66 at 13.7 years to .31 at 17.2 years (Table 7). However, when for these same chronological age intervals skeletal age is correlated with the per cent of mature height attained at that time, the r's are above .80 and remain consistently high. For the ages 13.7 through 16.7 they range from .85 to .89. At 17.2 years the r drops to .81. The distribution at this age is not normal because it is the age arbitrarily chosen as 100 per cent. If all of the measures were perfectly reliable one might expect the r at 17.2 to approach 1.00 and at adjacent ages to lie very close to this. But there is some error both in the measurement of height and in the assessment of skeletal age. Furthermore, there is a ceiling, an upper limit in both skeletal age and height when expressed as per cent of mature size. These ceilings restrict the S.D.'s as the upper ages are approached. The combination of restricted range of scores and imperfect reliability results in r's for these ages which are lower than if these attenuating factors were not operative. The same condition holds for the upper ages of the girls for the r's.

The closeness between this relationship of relative height and skeletal age is emphasized by contrasting it with the series of r's between relative height and chronological age when skeletal age is held constant (i.e., is limited to a six-month range). For a given skeletal age, the relation between chronological age and per cent of mature height is small. These r's run from -.06 to + .58, the latter relatively high r being an exception: in general, the r's are of the order of .25.

[7] *The graphic formulation of these charts was devised by Dr. Harold E. Jones.*

Figure 2

RELATIVE HEIGHT
(Boys)

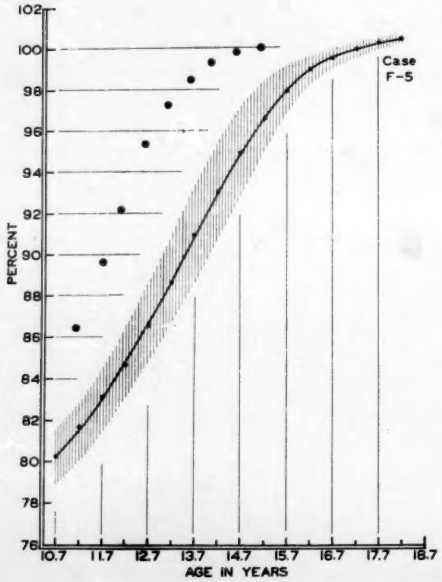


Figure 3

RELATIVE HEIGHT
(Boys)

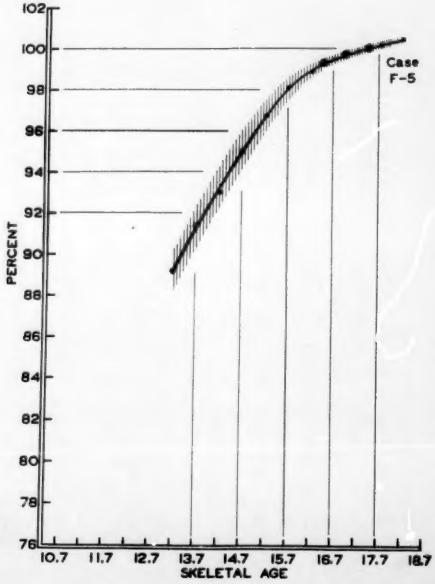


Figure 4

RELATIVE STEM LENGTH
(Boys)

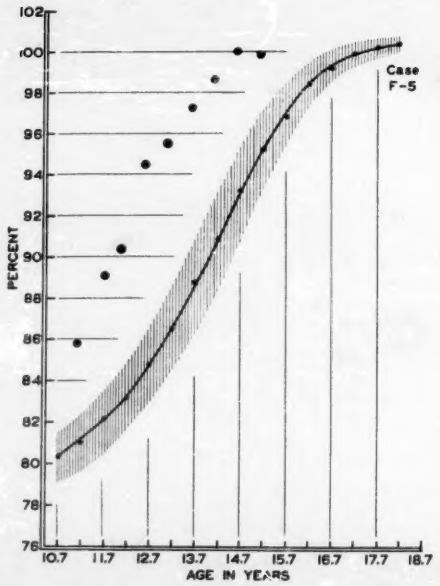


Figure 5

RELATIVE STEM LENGTH
(Boys)

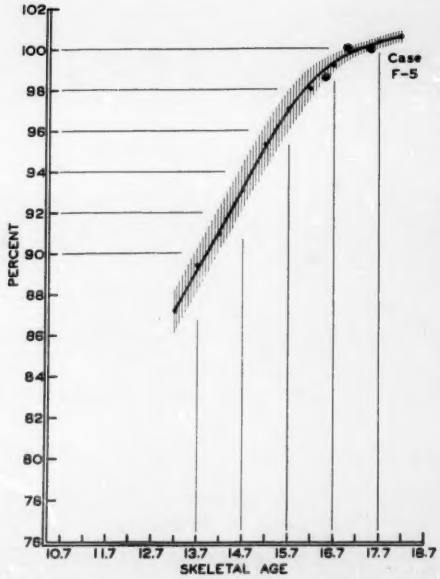


Figure 6

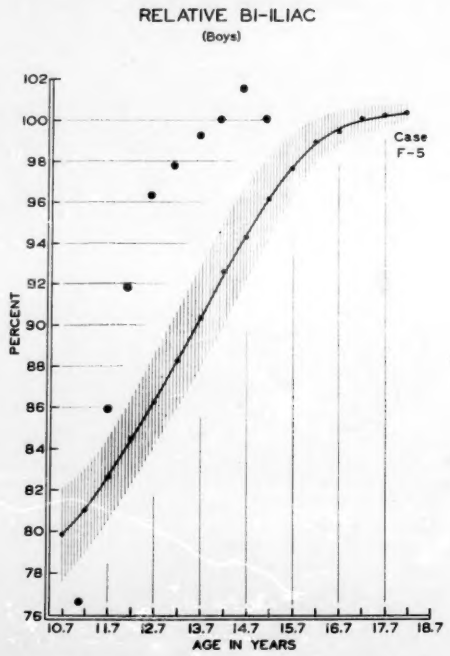


Figure 7

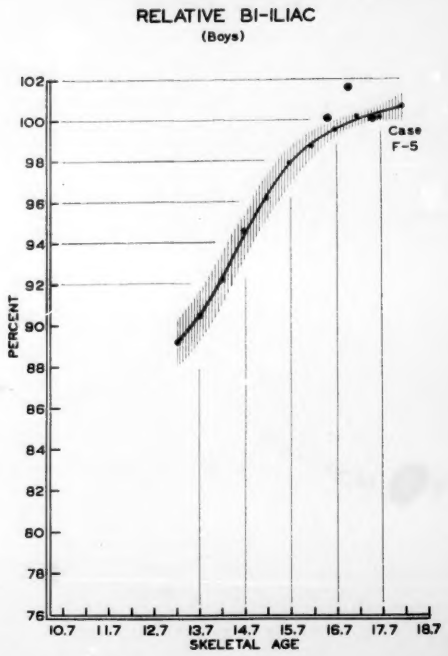


Figure 8

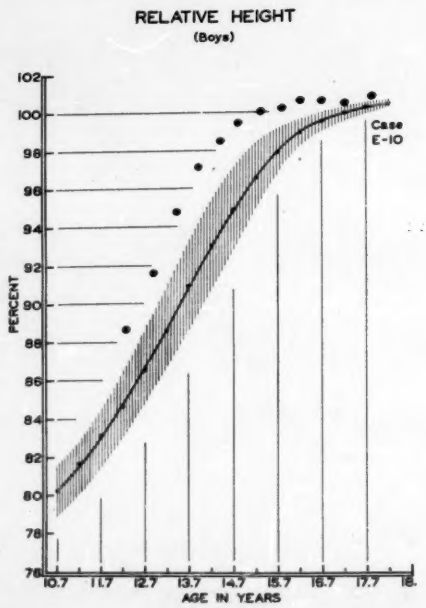


Figure 9

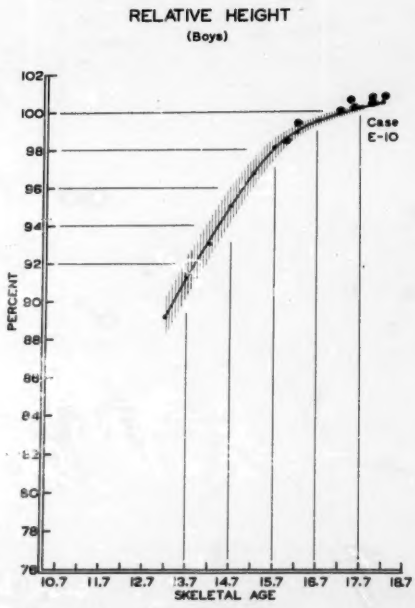
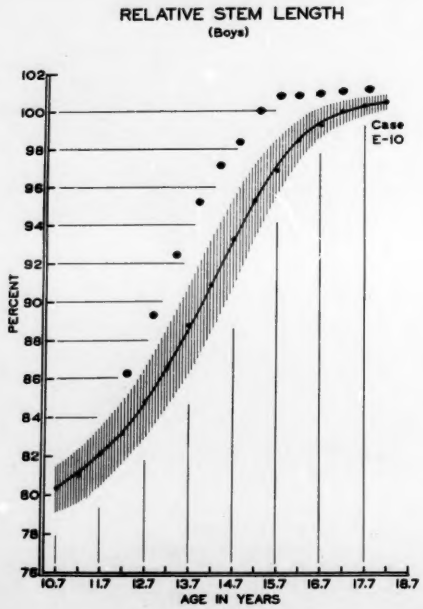


Figure 10



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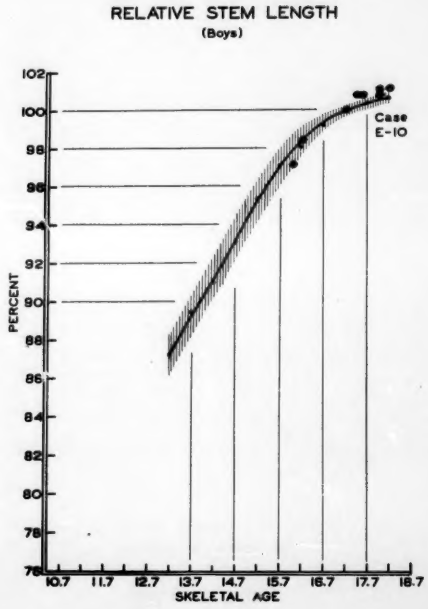


Figure 12

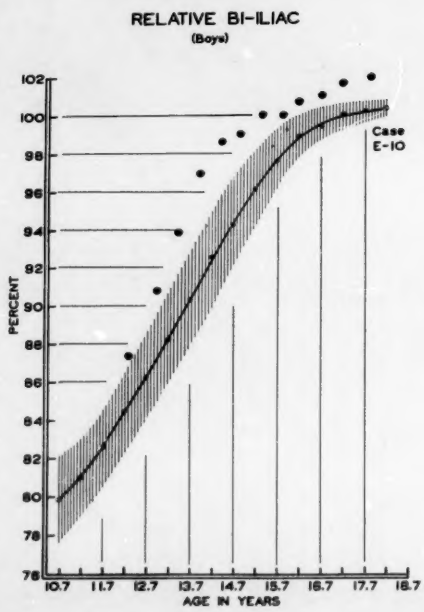


Figure 13

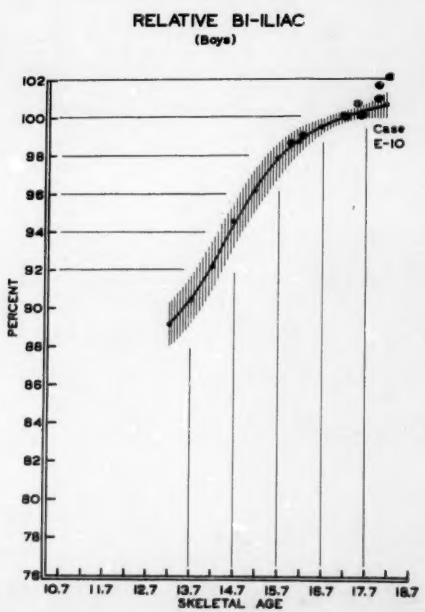


Figure 14

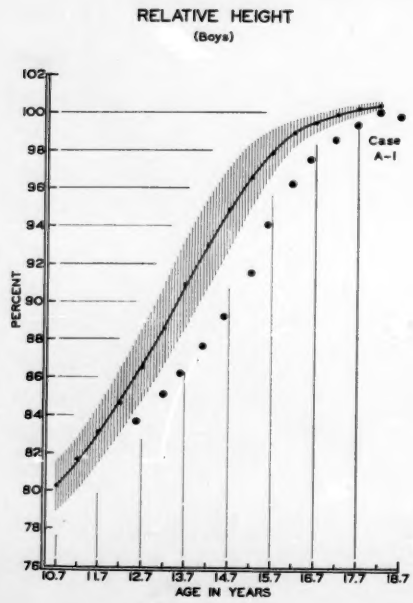


Figure 15

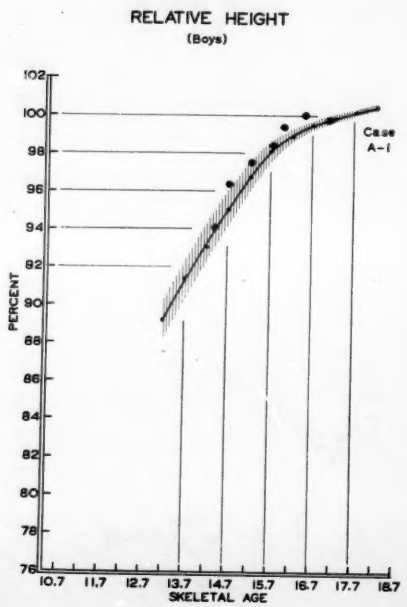


Figure 16

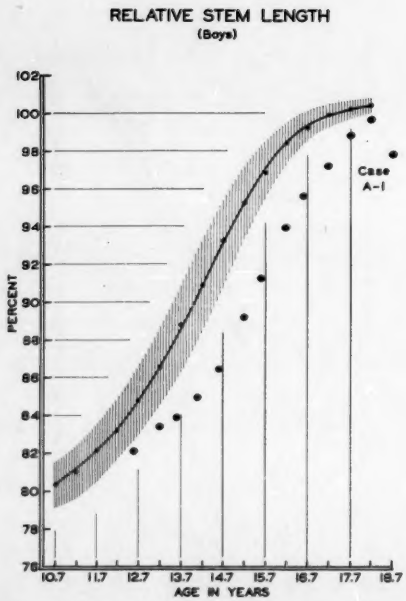


Figure 17

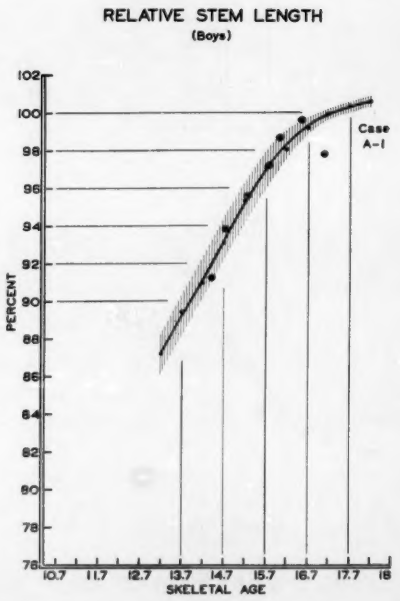


Figure 18

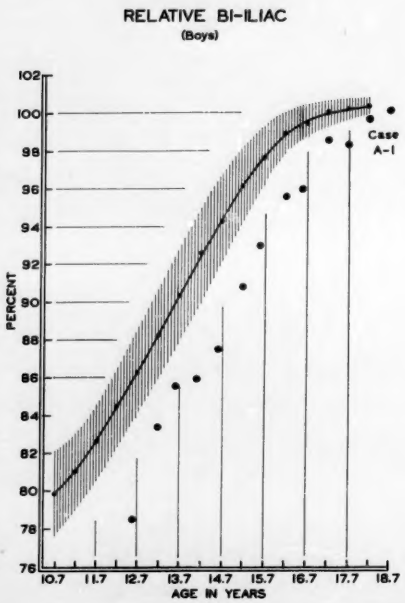


Figure 19

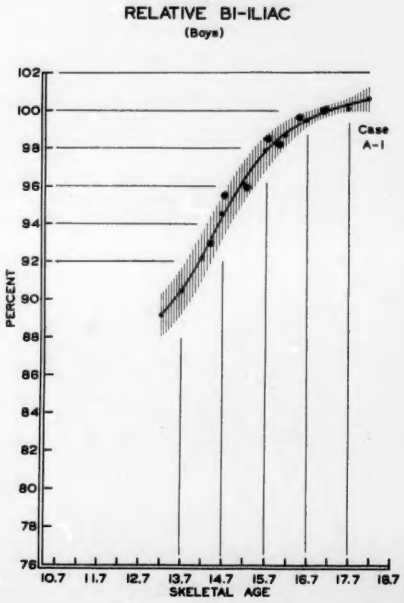


Figure 20

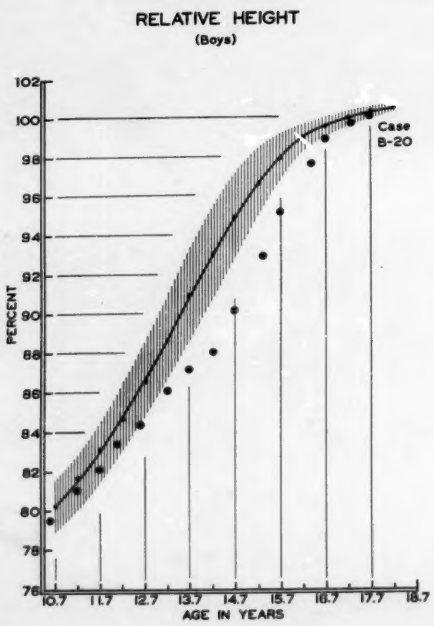
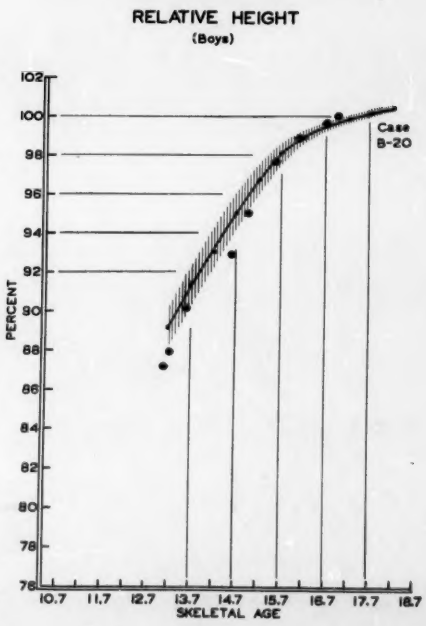


Figure 21



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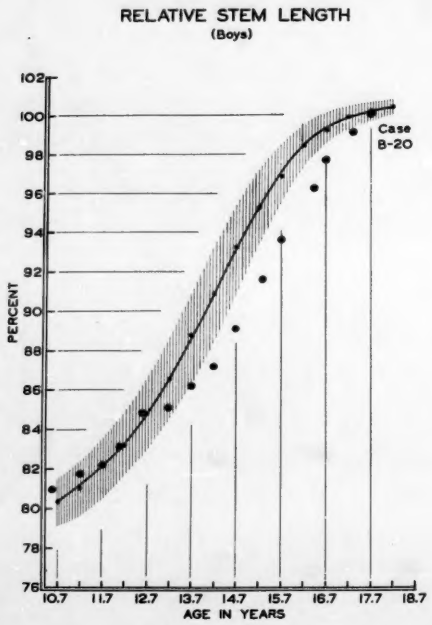


Figure 23

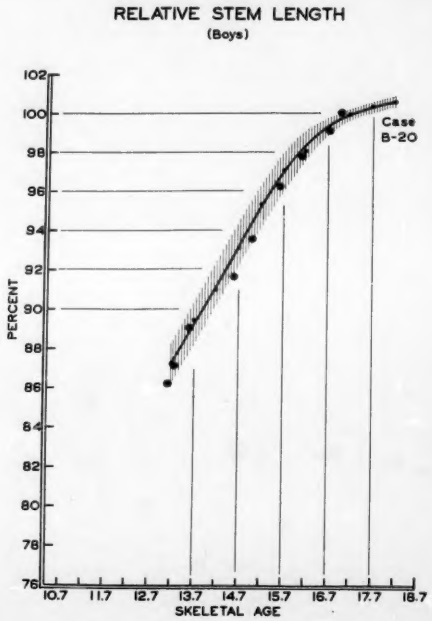


Figure 24

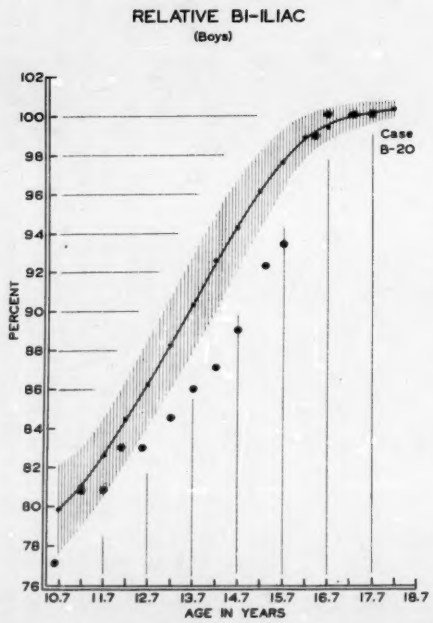


Figure 25

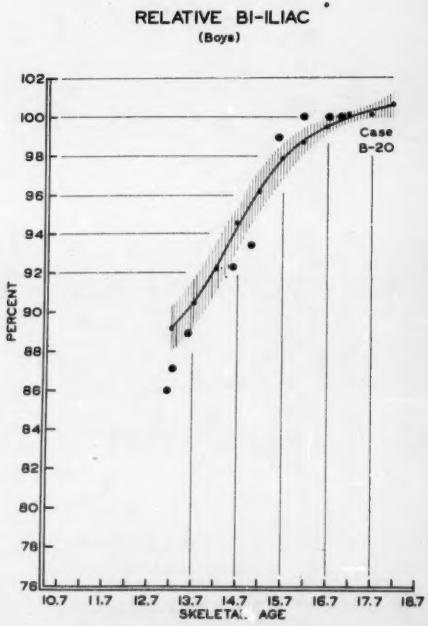


TABLE 7

HEIGHT CORRELATED WITH CHRONOLOGICAL AGE AND SKELETAL AGE

BOYS

Ages	Chronological Age n	Chronological Age Height in Centimeters by Sk. A. r	Chronological Age Per Cent of Mature Height by Sk. A. r	Skeletal Age n	Skeletal Age Per Cent of Mature Height by C.A. r
13.2	-	-	-	21	-.04
13.7	34	.66	.88	22	-.06
14.2	61	.64	.88	38	.58
14.7	72	.59	.89	47	.14
15.2	69	.46	.89	52	.24
15.7	71	.40	.86	58	.39
16.2	64	.35	.85	55	.32
16.7	69	.15	.87	60	.27
17.2	63	.21	.81†	**	**
17.7				44	.29
18.2				34	.04

GIRLS

13.2	-	-	-	16	-.10
13.7	42	.08	.85	18	.56
14.2	58	.16	.86	27	.46
14.7	65	.07*	.82*	37	.29
15.2	63	-.03*	.82*	49	.02
15.7	53	-.15*	.87*	53	.01

†Not normal, because this age is 100 per cent, and all but smoothed cases fall into one category.
*Skewed distributions because of Sk. A. "ceiling" of 16.2 years. At 15.7 years, if all girls including those who have matured at an earlier age, are used by adding one-half year to the skeletal age for each half year after Sk. A. 16.25, the number of cases becomes 64 and the r between per cent of mature height and skeletal age becomes .89.
**Skewed distributions.

Subjecting the data for the girls to the same correlational analysis (Table 7), we find (over the short age range for which the comparisons can be significantly made) similarly high r's between skeletal age and per cent of mature height. The girls' measures show somewhat less relation than the boys' between absolute height and skeletal age, and a slightly greater relation between per cent of mature height and chronological age. However, when we take into account the small range over which the girls' data are significant it is difficult to say whether these slight sex differences are due to more than chance. The correlations for both sexes are similarly high between per cent of mature height and skeletal age at any chronological age.

Similar relations between per cent of mature size and skeletal age are found for four other measures - stem length, weight, bi-iliac diameter, and chest circumference (Table 8).

TABLE 8

CORRELATIONS BETWEEN SKELETAL AGE AND PER CENT MATURE STEM LENGTH, BI-ILIAC DIAMETER, WEIGHT AND CHEST CIRCUMFERENCE

C. A.	Stem Length		Bi-iliac Diameter		Weight		Chest Circumference	
	n	r	n	r	n	r	n	r
BOYS								
13.7	34	.86	34	.77	34	.75	34	.66
14.2	61	.85	61	.77	61	.81	61	.72
14.7	72	.89	72	.86	72	.87	72	.81
15.2	69	.89	69	.80	69	.78	69	.74
15.7	71	.84	71	.77	71	.83	71	.71
16.2	64	.84	64	.74	64	.76	64	.64
16.7	69	.82	69	.66	69	.81	68	.65
17.2	63	.78	63	.53	63	.78	62	.62
GIRLS								
13.7	42	.85	42	.82	42	.74		
14.2	58	.84	58	.85	58	.66		
14.7	65	.85	66	.74	66	.64		
15.2	61	.86	63	.85	65	.78		
15.7	64	.81	64	.55	64	.50		

The relation to skeletal age is closest for height, then come stem length and weight, with bi-iliac diameter and chest circumference relatively low (r's on the latter range from .62 to .81 for boys). These lower r's might be accounted for in three ways: (a) these last two measures are less reliable than the first three (3, 7); (b) the bi-iliac, being a smaller, less variable measure, does not differentiate size as well as do the other measures. Furthermore, the increments with age are relatively small for both bi-iliac diameter and chest circumference. But (c) it is also possible that the transverse dimensions are not as closely related to skeletal maturity as are the vertical dimensions in which growth of the long bones used in the assessments is more obviously involved. Support for this latter interpretation is given by the r's for weight, as it partakes of both longitudinal and transverse dimensions, and though very reliable, and showing high variability and large increments with age, it falls in between the two types of measure in the size of the correlations. Probably all three factors are operative.

From the evidence thus far presented, we should expect growth in size to be most consistent when expressed in relation to a child's skeletal development. In order to determine whether this is true, we have computed correlations for consistency of height in boys, using 17.2 years as the adult standard with which to compare earlier measurements of height. The re-

sulting r's are shown in Table 9 and Figure 26. Height (in cm.) at C. A. 17.2 is correlated with height at seven earlier ages. These r's, as would be expected, are high at ages near to 17.2, (.98 with height at C. A. 16.7) and drop as the age interval between measures increases (to .83 and .84 at C. A.'s 14.2 and 15.7, respectively). But C. A. 17.2 includes a range of several skeletal age years: half of the boys will have attained their full stature at this age or before, but the others will continue to grow - some of them for several years. Although we can predict height at 17.2 years with fair accuracy at 14 years, this does not mean we can predict adult height with equal accuracy. This is illustrated in the series of r's between height at earlier C. A.'s with "mature" height, that is, height at Sk. A. of 17.2 years. In this series the r's at C. A.'s 13.7 and 14.2 have dropped to .69. However, if we correlate height at earlier skeletal ages with height at Sk. A. 17.2, the r's although they drop to .87 at 14.2 years, are at all ages higher than for the corresponding C. A. groups, and the r between Sk. A.'s 13.7 and 17.2 is .92.

It is of interest to note that the prediction of height is poorest at 14.2 years by all three sets of comparisons. This is usually considered to be the age at onset of puberty for most boys. But it is also an age which is composed of boys of greatly differing physical maturities - due to the combined factors of individual differences in age at puberty and the rapid and marked changes which occur once the growth spurt starts in a child. Development at this stage appears to be more chaotic than at earlier or later stages, and ordinarily related aspects of growth tend to fall out of step with each other. It is not a good age at which to make predictions in boys' height.

Correlations for consistency of height have been computed in a similar way for the girls, using 16.2 years, or complete skeletal maturity, as the basis for comparisons (Table 9). Again, as for the boys, we find that the highest r's occur between skeletal age groups, and that the lowest r's are between mature height at skeletal age 16.2 and height at earlier chronological ages. The r's for the girls are in most instances higher than those for the boys. This may be attributed to the fact that the data for the girls cover a shorter and relatively more mature section of their growth, - a section in which on the average very little growth in height takes place.

To summarize, among boys of the same chronological age, the skeletally more mature boys are nearer their own mature size, the immature boys less near. When size is expressed in terms relative to the boys' own mature size, there is a high relationship, at all chronological ages studied, between skeletal maturity and relative maturity in height; the relation is also high for stem length, somewhat less for weight, and still less,

TABLE 9

CORRELATIONS SHOWING CONSISTENCY OF GROWTH IN HEIGHT

BOYS

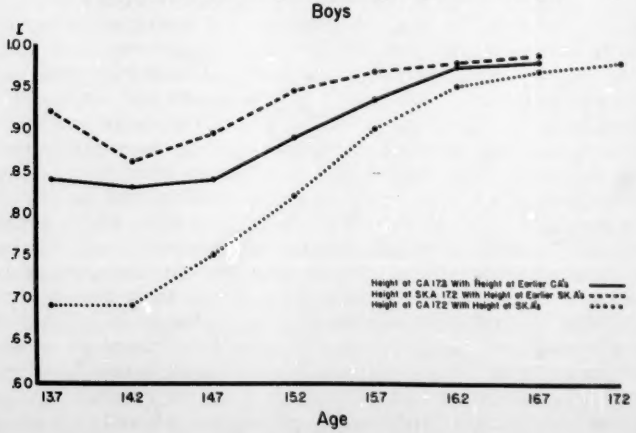
Ages	Ht. at C.A. 17.2 with Ht. at Earlier C.A.'s n	r	Ht. at Sk.A. 17.2 with Ht. at C.A.'s n	r	Ht. at Sk.A. 17.2 with Ht. at Earlier Sk.A.'s n	r
13.7	63	.84	77	.69	31	.92
14.2	60	.83	77	.69	49	.87
14.7	63	.84	77	.75	60	.89
15.2	59	.89	76	.82	67	.94
15.7	61	.94	75	.90	73	.97
16.2	56	.98	74	.95	75	.98
16.7	61	.98	73	.97	76	.99
17.2	-	-	68	.98	-	-

GIRLS

	Ht. at C.A. 16.2 with Ht. at Earlier C.A.'s n	r	Ht. at Sk.A. 16.2 with Ht. at C.A.'s n	r	Ht. at Sk.A. 16.2 with Ht. at Earlier Sk.A.'s n	r
13.7	67	.88	70	.85	25	.98
14.2	68	.93	71	.90	36	.99
14.7	67	.97	70	.95	47	.99
15.2	64	.98	66	.95	59	.99
15.7	61	.99	64	.95	65	.99
16.2	-	-	68	.98	-	-

Figure 26

Correlations Showing Consistency of Growth in Height
Boys



but definitely positive, for bi-iliac diameter and chest circumference. The small though positive r's between chronological age and percentage of mature height indicate that there is possibly a slight tendency among boys of the same skeletal age for the chronologically older boys to have more nearly completed their growth. Correlations for consistency of growth are highest when computed between skeletal age groups. If one were to attempt to predict a child's mature height, fairly accurate prediction would seem possible from skeletal age. Given his skeletal age, from which per cent of mature height can be estimated, and his height at the time the x-ray was taken, probable mature height, or 100 per cent, can be readily computed. It is just possible that a correction for chronological age would improve the accuracy. That is, as suggested by the r's in the last column of Table 7, late-maturing boys may be relatively taller for their skeletal age. However, data on other samples will be needed to determine whether this is true, generally, and whether such a correction is advisable.

As for the girls, for a given chronological age (above 12 years), there is no relation between absolute height and skeletal age when C. A. is controlled, but again we find a close relation between skeletal age and relative height in terms of per cent of the girls' own mature statures. But among the girls chronological age seems to have some importance, in the earlier ages studied, and accurate prediction of a girl's mature height would seem to be in part also dependent on her chronological age up through about 14 years. Correlations for consistency in absolute height show that prediction of mature height is greater from skeletal age that from chronological age criteria. It must be kept in mind, however, that significant data for the girls are available for only a very short age range. The correlations between skeletal age and per cent of mature stem length, bi-iliac diameter and weight are also positively correlated in the girls, with weight showing the lowest relationships. Probably growth in width of the hips is a more significant indicator of maturing in the girls that it is in the boys because of the sex differences in body build which develop during these ages. However, the differences among the r's of these various measures with skeletal age are small, and may not be significant. In all instances, the r's are strongly positive, although some of them drop considerably at the latest ages, as maturity is approached. The measures which show this drop in r's are, for both sexes, primarily transverse dimensions: the lower r's may be a function of the increased influence, at the level where growth changes are very slight, of the three factors mentioned above - factors which would account for the lower r's with these measures at all ages. These are: low reliability, insignificant changes with growth, and smaller relationship to the skeletal areas involved.

PER CENT OF MATURE SIZE COMPARED WITH RATES OF MATURING

There is a spread of about 4 years in the ages at which the boys in this study reach a skeletal status of 17 years, 3 months: and a spread of an estimated 3.5 years in the girls' ages at reaching complete epiphyseal closure. In several researches in recent years it has been shown that various factors in physical maturing are related to rates of bone development. As there is some slight correlation between C. A. and growth in size we may find some characteristic differences in the growth trends of slow and fast maturers. A number of investigators, for example Shuttleworth (9), and Richey (8), have used such developmental landmarks as menarche and age at most rapid growth as criteria for grouping children according to their relative maturity. They have then compared early-, average-, and late-maturing groups in various ways. We have approached this problem by dividing all of the children into early-, average-, and late-maturing groups on the basis of their skeletal maturity. The girls are classified in three groups, according to the age at which they first reached the skeletal age of 16 years, 3 months; and the boys are divided similarly, according to the age at which they attained the skeletal age of 17 years, 3 months. The division has been made so that for both sexes the means of the chronological ages for the three maturity groups are approximately one year apart at maturity, with the girls of each group being advanced about two years over the boys in the corresponding group. The number of cases for the early-, average-, and late-maturing groups, respectively, are for the girls, 25, 27, and 19; for the boys, 21, 35, and 21. The data in Table 10 show that the skeletal age differences between the groups are maintained over the age period for which we have x-rays.

Let us compare the relative growth rates of these early-, average-, and late-maturing groups. The means and S.D.' s for per cent of mature height are shown for these groups in Table 11; the means have been plotted, with the curves adjusted to make skeletal maturity in the groups approximately equivalent, in Figures 27 and 28. It is evident from the table that, for their C. A.'s, the late-maturing groups are retarded and the early-maturing groups accelerated in growth relative to their eventual mature height. However, the adjusted curves show in both sexes a tendency for the late-maturing groups to be relatively nearer mature height for their skeletal ages than the early-maturing groups, though the differences are not significant. It appears from these curves, as well as from the correlation coefficients, that if we wish to predict mature height as early as 13 or 14 years of age, accuracy of prediction might be increased if deviations from the average age of maturing were taken into account.

TABLE 10

MEANS AND STANDARD DEVIATIONS (S.D.) OF SKELETAL AGE SCORES AT GIVEN CHRONOLOGICAL AGES OF GROUPS DIVIDED ACCORDING TO AGE AT REACHING MATURE SKELETAL STATUS

	Early-Maturing			Average-Maturing			Late-Maturing		
C.A.	n	Mean	S.D.	n	Mean	S.D.	n	Mean	S.D.
BOYS									
13.7	7	14.9	.37	16	13.7	.52	6	13.1	.45
14.2	14	15.4	.55	28	14.1	.52	17	13.5	.52
14.7	18	15.9	.56	31	14.6	.57	17	13.8	.46
15.2	19	16.5	.59	34	15.3	.55	20	14.4	.56
15.7	14	16.8	.51	33	15.8	.49	21	15.0	.43
16.2	17	17.2	.51	33	16.3	.40	17	15.5	.39
16.7	15	17.8	.40	32	16.8	.43	20	15.9	.44
17.2	17	18.0	.24	31	17.4	.45	19	16.4	.33
GIRLS									
13.7	12	15.0	.77	14	13.7	.38	8	13.2	.46
14.2	19	15.6	.54	23	14.5	.51	14	13.5	.66
14.7	23	16.0	.40	26	15.0	.50	19	14.0	.65
15.2	25	16.2*	.23*	26	15.4	.45	16	14.6	.53
15.7	25	16.2	-	22	15.8	.37	18	15.0	.50

*Three previously mature cases placed at 16.5 Sk.A.

FACTORS AFFECTING GROWTH IN INDIVIDUAL CASES

Other possible factors which might influence growth in size, apart from skeletal age, may be discovered through an examination of the relative growth rates of individuals. In the comparison of growth rates we may consider a number of hypotheses, one of which pertains to the health of the subjects in question. If illness should retard growth in size but not the process of skeletal maturing (10), then we might expect poorer prediction from those cases who have had the most severe illnesses. Todd took care to emphasize in his norms the areas of the skeleton which he regarded as least affected by disturbances in health. It seems possible, therefore, with the skeletal ages based on his norms, that we may find periods of delayed growth in size with little or no retardation in skeletal maturing. This condition could be investigated in three ways: (a) by selecting those cases for whom prediction is poorest and investigating their health histories; (b) by selecting children with histories of illness and poor health, and then examining the growth rates of their relative (per cent mature) size; or (c) by examining the x-rays for indications of interruptions in growth.

The greatest inaccuracies in prediction occur, of course, at the ages most distant from the terminal point used as 100

TABLE 11

MEANS AND STANDARD DEVIATIONS (S.D.) OF PER CENT OF MATURE HEIGHT FOR EARLY, AVERAGE, AND LATE-MATURING CHILDREN GROUPED ACCORDING TO C.A. AT REACHING COMPLETE SKELETAL MATURITY

BOYS

C.A.	Early-Maturing n	Mean	S.D.	Average-Maturing n	Mean	S.D.	Late-Maturing n	Mean	S.D.
10.7	7	83.2	.9	19	80.0	1.3	12	79.2	1.6
11.2	13	83.5	2.0	24	81.6	1.5	12	80.0	1.8
11.7	19	85.3	2.5	30	82.8	1.4	18	81.3	1.3
12.2	16	87.4	2.6	33	84.4	1.4	18	82.5	1.5
12.7	20	89.6	3.0	35	86.2	1.5	20	83.8	1.5
13.2	19	92.3	2.8	34	88.4	1.7	20	85.4	1.6
13.7	21	94.8	2.4	33	90.7	1.9	21	87.0	1.6
14.2	19	96.9	1.8	32	93.2	1.9	20	88.9	2.0
14.7	20	98.1	1.4	34	95.3	1.6	21	91.2	2.0
15.2	17	99.0	.9	34	97.0	1.2	19	93.6	2.0
15.7	17	99.5	.5	33	98.4	.7	21	95.9	1.5
16.2	15	100.1	.4	31	99.2	.5	18	97.8	1.0
16.7	16	100.2	.4	34	99.8	.3	20	98.6	.7
17.2	15	100.6	.5	29	100.1	.2	20	99.3	.5
17.7	14	100.6	.3	23	100.3	.2	19	99.9	.4

GIRLS

10.7	12	89.6	2.4	12	86.5	2.3	8	84.6	1.8
11.2	17	91.8	2.3	23	88.8	2.5	11	85.2	1.4
11.7	23	93.9	2.5	24	91.0	2.5	18	87.3	1.9
12.2	22	95.6	2.3	25	92.8	2.3	18	90.0	2.1
12.7	25	97.2	1.6	26	95.1	1.6	17	91.8	2.0
13.2	22	98.2	.9	25	96.9	1.1	18	94.3	2.3
13.7	24	98.9	.9	27	98.0	.7	20	95.6	2.3
14.2	25	99.4	.5	27	98.7	.5	19	96.8	1.8
14.7	25	99.8	.3	26	99.0	.8	19	97.9	1.2
15.2	23	100.0	.2	25	99.5	.4	18	98.7	.9
15.7	24	100.2	.3	22	99.8	.2	18	99.2	.6
16.2	23	100.2	.3	27	99.8	.2	18	99.4	.2
16.7	22	100.3	.3	25	100.1	.2	18	99.7	.2
17.2	22	100.4	.2	22	100.2	.2	19	99.9	.2
17.7	18	100.5	.2	15	100.2	.2	15	100.1	.2

per cent. Furthermore, if we would predict adult height we should like to do so at the earliest possible ages. We have, therefore, selected for consideration all cases who deviate 1 S. D. or more from the means (of per cent of mature height) for the skeletal ages of 13.2, 13.7, and 14.2 years. There are 16 boys and 15 girls who fall into this deviate category at least once in the three age levels. If prediction of mature height were attempted at 13 to 14 years on these cases, using the method suggested on page 32, there would be considerable error in the estimates.

Figure 27

Percent Mature Height Attained by Early, Average and Late Maturing Girls Adjusted for Skeletal Age

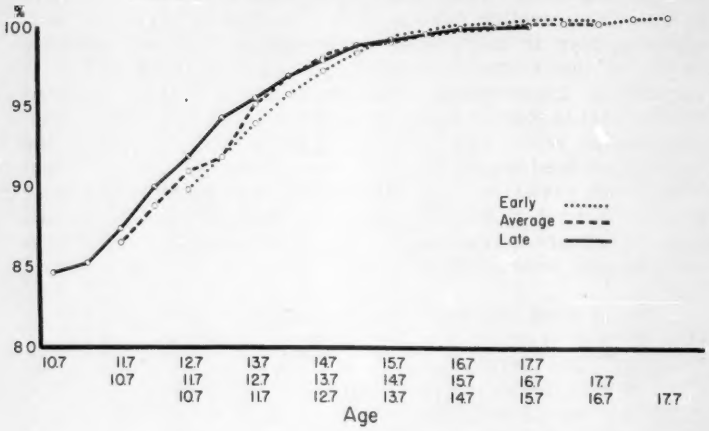
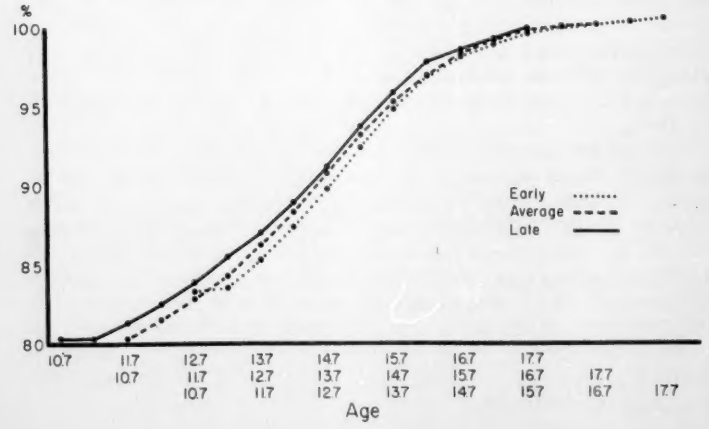


Figure 28

Percent Mature Height Attained by Early, Average and Late Maturing Boys Adjusted for Skeletal Age



Of the 16 boys in this group, 7 are late-maturing, 9 are average-maturing, and none early-maturing. Nine deviated below the mean and 7 above: i.e., mature height would be underestimated for 9 and overestimated for 7. Among the average-maturing boys, 5 are above the mean, 4 are below; of the late-maturing cases, 5 are below and only 2 above. There is a slight suggestion here that the eventual height of the late-maturing boys is more likely to be underestimated, while the height of the early-maturing boys can be predicted most accurately. Inspection of the growth curves of these deviates reveals that in some instances the error in prediction may have been due to error in measuring height at maturity, or in the skeletal age used as a standard.[8] In most instances (10 of 16 boys) even though deviation from the skeletal age norm seems to be large, it is much closer than to the chronological age norm, and even though prediction from skeletal age seems poor, it is a considerable improvement over prediction from chronological age.

The 15 girls who deviate widely show a similar selection. Nine are late-maturing, 5 are average-, and only one early-maturing. The deviations of 7 are above the mean (cases in which mature height would be overestimated) and 8 are below (cases who would be underestimated). Of the average-maturing girls, 2 are below and 3 above the mean; of the late-maturing girls, 5 are below and 4 above; the one early-maturing girl is below the mean. In terms of age at maturing there is no selective factor operating toward either over or under estimating mature height.

In general, for both sexes prediction seems best for the early-maturing cases; among the girls there is some indication that it is poorest for the late-maturing. This difference may be no more than is to be expected from the fact that prediction becomes less accurate as the deviation from maturity increases. This decrease in accuracy of prediction with longer intervals from maturity is indicated in the r's for consistency shown in Table 9.

It seemed possible that these poor-prediction cases (ruling out those which appear to be the result of errors in measurement or assessments) might be generally uneven in their relative maturity in different growth processes. For example,

[8] *17.2 years represents the mid-point of a six-month interval of skeletal ages. An individual might fall at the extreme of this interval, or he might, during the six months between taking x-rays, have matured so rapidly as to have missed this interval entirely. In the latter case heights and skeletal ages had to be interpolated between the preceding and succeeding ages and measures.*

the deviate girls might also be more than ordinarily deviate in age at menarche as related to their skeletal age. If this were true we might expect the skeletal age deviation from menarche to be greater for this group of girls than for an average group. A study of these cases showed no tendency in this direction. Nor is there any consistent directional tendency for menarche to deviate with the relative height deviations. The mean age at menarche is a little late (13.9 years S. D. .91) as compared with 13.2 years (S. D. 1.31) for the entire group, but this is to be expected in a group which is predominantly late-maturing.

An example of a relative growth rate which shows wide deviation from the mean in terms of his skeletal age is Case A 15 (Figures 29 and 30). An attempt to predict his mature height at 14 years would have resulted in considerable underestimation. His skeletal deviations from his chronological age show him to have been about average at the first two x-rays, at 14.0 and 14.5 years, but with a slowing down of rate of skeletal maturing which continues to 17.1 years, after which he again spurts and by 18.1 years is only .4 of a year retarded. An inquiry into the health factors which might have disturbed his growth revealed that during this period he underwent an operation on his breasts because of tumorous growths.

It is also possible that growth rates are influenced by glandular dysfunctions. (Case A 15 may be an instance.) Among the cases in this study there are none with marked glandular disturbance, but the physician[9] who examined them has selected 6 boys in the study who at some part of their adolescent growth period were considered to be physically "sex-inappropriate", with atypical distributions of fat and other physical characteristics which would indicate a temporary glandular dysfunction. Three of these boys are late-maturing, 2 are classed as average, but tend at most ages to be slightly retarded skeletally, while one is at most ages somewhat accelerated, but not markedly so. If their condition is due to a temporary gonadal dysfunction, it might be expected that during this period epiphyseal union would be delayed while the processes of growth in size would continue at the rate customary for that stage of skeletal development. This would result in an eventual height well above the expectancy based on data secured before the disturbance occurred. An examination of the relative growth curves of these boys indicates that this supposition may be true to some extent. Data on per cent of mature height are available for 5 of the boys (one did not attain sufficient bone maturity within the period of the study). Of these 5, 2 are close to the mean at all ages while 3 deviate at least to some extent in the expected direction. For 2, the deviation is slight and for

[9] *Dr. Herbert R. Stolz.*

Figure 29

RELATIVE HEIGHT

(Boys)

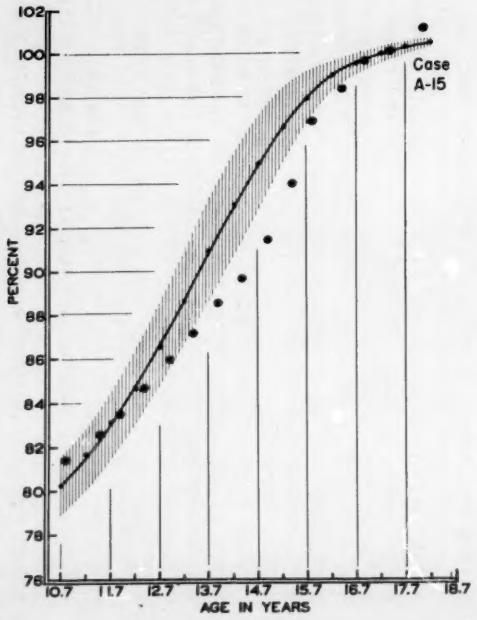
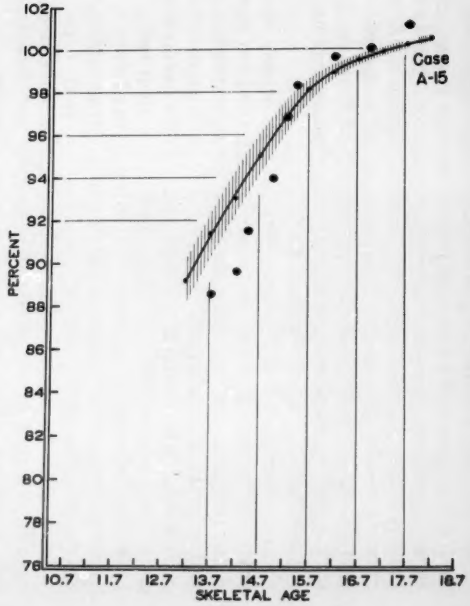


Figure 30

RELATIVE HEIGHT

(Boys)



one, considerable. That is, in the early part of their skeletal age ratings, height is relatively short, and prediction at those ages would have been for a shorter adult height than was attained. However, 3 out of 5 cases is only suggestive, and further data on a much larger number of cases would be necessary to test adequately such an hypothesis as here suggested.

A search for conditions in the bone which might be related to interruptions in growth revealed, among the boys, 5 cases with clear, marked transverse lines which are considered to be indicative of temporary cessations of growth. There were, in addition, 17 cases with light, sometimes barely discernible transverse lines, and 11 cases with slight anomalies of the bones (blurred edges, poor mineralization, areas of decalcification, and fractures), a total of 33 cases.

Among the 16 boys for whom prediction of height was poor, only 6 are in this group of 33, and only 2 are among the 22 with transverse lines. It appears that illnesses which temporarily disturb the growth of the bones do not operate to make prediction of adult height poorer.

There is some indication, however, that factors which have caused the transverse lines found in the bones have operated to delay skeletal maturing as well as growth in size. The 22 cases with transverse lines are divided into maturity groups as follows: 2 early, 10 average, and 10 late maturers - a definitely skewed distribution. Furthermore, among the 5 with definite transverse lines there are no early maturers, but 3 are average and 2 late. Even though Todd selected for his criteria of maturing, areas which he found to be least subject to disturbance, there appears still to be some connection between slower maturing and evidences in the bones of interrupted growth (11). Our x-rays do not by any means catch all of the indications of retardation in growth, because they are restricted to only two areas of the skeleton, and to only the last few years of the children's growth.

As a tentative conclusion, it would appear from this comparison that illnesses may affect rates of growth, both in size and in maturity of the skeleton, and that these changes are likely to be concurrent.

THE SEXES COMPARED FOR RELATIVE GROWTH RATES

So far the discussion in this section has been in terms of the sexes taken separately. Absolute rates of maturing in the sexes differ markedly and this sample is no exception (Figures 31, 32, 33, and 34). To what extent are the relative growth rates similar when adjustment is made to make bone maturity equivalent? In Figure 35 the boys' and girls' per cent mature height curves are plotted with the ages adjusted to approximate equivalence in skeletal maturity. Figure 36 gives the curves

Figure 31

Average Curve of
HEIGHT

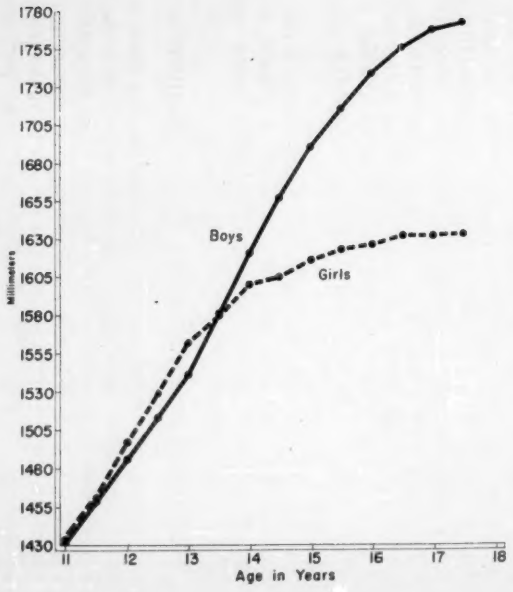


Figure 32

Average Curve of
STEM LENGTH

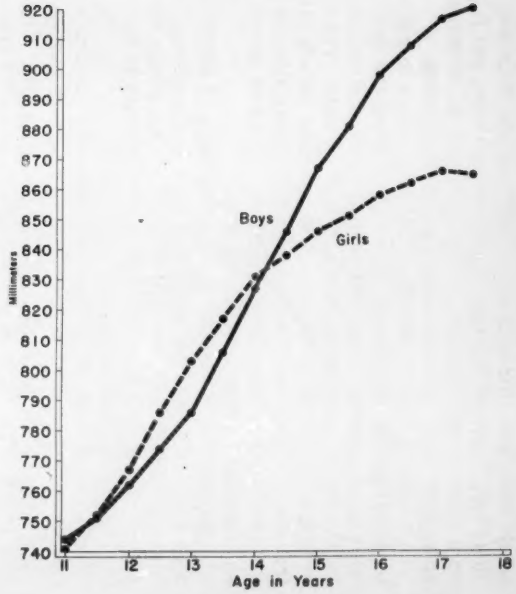


Figure 33
Average Curve of
BI-ILIAC

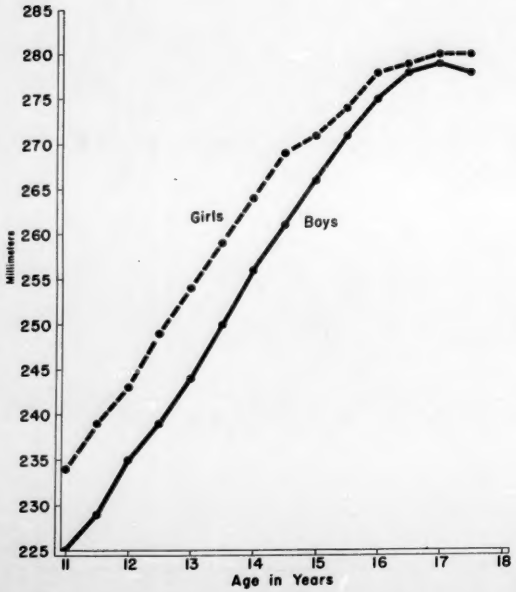


Figure 34
Average Curve of
BI-ACROMIAL

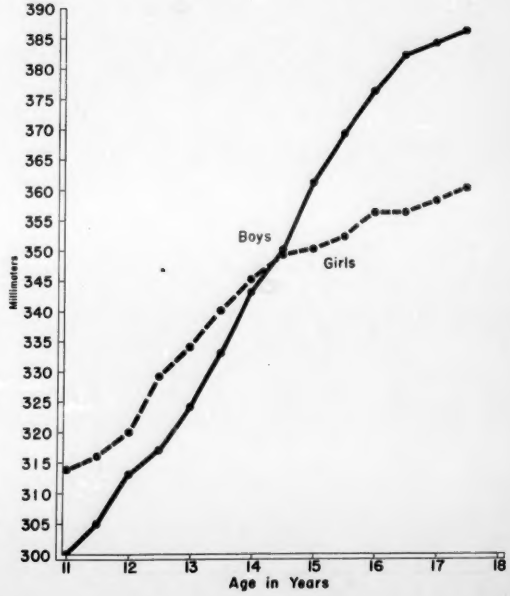


Figure 35

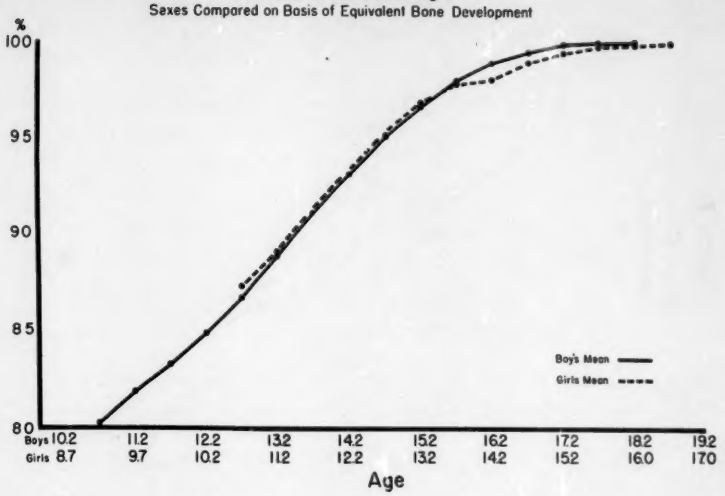
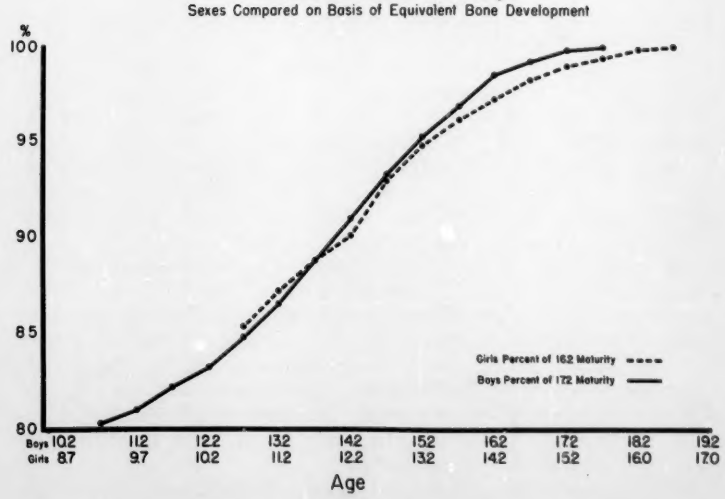


Figure 36


Percent of Mature Stem Length
Sexes Compared on Basis of Equivalent Bone Development
%
100
95
90
85
80
Girls Percent of 16.2 Maturity
Boys Percent of 17.2 Maturity
Boys 10.2 11.2 12.2 13.2 14.2 15.2 16.2 17.2 18.2 19.2
Girls 8.7 9.7 10.2 11.2 12.2 13.2 14.2 15.2 16.0 17.0
Age

for stem length plotted in the same way. In both measures the curves for the sexes are very similar, but there is some indication that the girls are more nearly their mature size in the early half of the curve. This would be more apparent if the percentages for both sexes had been computed from complete skeletal maturity. As it is, the 100 per cent point for boys lacks a year of being complete. If the percentages were directly comparable the curves would not cross, but would tend to coincide at the later ages.

SUMMARY

The left hands and knees of a group of adolescent children, 90 boys and 87 girls, were x-rayed nine times at six-month intervals (at average ages of 14 to 18 years). Anthropometrics were taken at the same ages. Assessments of bone maturity, by means of the Todd standards, proved to be reliable. Skeletal ages based on the combined hand and knee assessments showed fairly consistent growth trends, the r for boys between ratings three years apart being .80.

Comparisons have been made between skeletal maturing and rates of growth in size. When expressed as per cent of a child's eventual mature size, his growth is seen to be very closely related to the development and maturing of his skeleton. This is shown to be true for the group as a whole, in several different ways. Standard deviations from the mean are seen to be much smaller when the cases are grouped according to skeletal age than when grouped according to chronological age. Correlations between different measures at each age group give higher r's with skeletal age, and when expressed as per cent of mature size. Correlations for consistency in height over a period of years are greater between skeletal age groups. This also holds when comparisons are made among children who mature at different rates, though the late maturers seem to be least predictable - perhaps only because they are farther from their goal at any given C. A. In individual cases whose percentage height is not closely related to skeletal age, we could find little evidence that the disparity was due to other than chance factors. However, there is some indication that illness and glandular hypofunction may operate to retard skeletal maturing and to effect growth in size.

When curves of growth are expressed as per cent of mature size at successive skeletal ages, we find a slight tendency for the late maturers to be a little nearer their mature height and the early maturers a little less so than the average - indicating a slight influence of other factors related to chronological age. When the sexes are compared in this way their curves of growth are seen to be remarkably similar.

It appears that growth in size is closely related to the

maturing of the skeleton. At a given skeletal age we may say that a child has achieved a given proportion of his eventual adult body dimensions. Consequently, mature size can be predicted with fair accuracy if a child's present size and skeletal age are known.

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